Issues and Policy Measures for Phosphorus Recycling from Sewage: Lessons from Stakeholder Analysis of Japan

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Abstract

While some local governments push ahead with recycling phosphorus from wastewater, there has been little progress nationwide. In this study, we analyzed the perceptions and interests of each stakeholder in this issue by conducting interviews to assess recycling approaches. In comparison with recycling in other fields, for instance, industrial materials recycling, the stakeholders involved in phosphorus recycling are far more diverse. This makes it more difficult to coordinate their behaviour. Based on interviews with a wide range of stakeholders, we identified seven dimensions that they consider vital for promoting phosphorus recycling: environment, cost, image, transaction stability, distribution, quantity and quality. Key challenges will be to develop technologies to slash costs, form *dosho-imu* alliances for simultaneous achievement of multiple objectives, and make bargaining arrangements among local governments, fertilizer manufacturers and cement producers to secure stable volumes.

Key words: Japan, phosphorus, recycle, sewage, stakeholder analysis

1. Necessity and Potential for Phosphorus Recycling

1.1 Growing interest in phosphorus management

Phosphorus is an essential element for all life, including human. We consume phosphorus through food, *i.e.*, meats and vegetables produced with fertilizers. The prime mode of phosphorus use is manufactured fertilizer, the phosphorus of which comes mainly from rock phosphate. Of particular importance in the context of Japan, however, is its industrial applications. These include metal surface treatments and other diverse applications.

There is increasing concern about the availability of phosphorus globally. Many years of mining have depleted reserves of high-quality, low-cost rock phosphate. Global phosphate prices surged in 2008. This has led to an international debate about so-called "peak phosphorus" (Cordell *et al.,* 2009; Vaccari, 2009; Nature Editorials, 2010; IFDC (International Fertillizer Development Center), 2010). Some worry that if we continue to extract phosphorus at current rates, the price of phosphorus, which is vital for daily living, could rise so high that agricultural and industrial production will suffer seriously (Ohtake, 2011).

Several initiatives led mainly by academia (Global Phosphorus Research Initiative (GPRI), Arizona State University and Global TraPs) have emerged. Among such initiatives, Global TraPs is unique in the sense that it takes a more holistic approach, involving not only academia but also industry, the public sector and international organizations.

At the international level, the United Nations Environment Programme (UNEP) in its report in 2011, chose the issue of phosphorus as one of three emerging issues and highlighted its importance (UNEP, 2011). Now UNEP is incorporating the management of phosphorus, in addition to nitrogen and other nutrients, in its Global Partnership on Nutrient Management (GPNM). The issue of phosphorus has even been taken up as one of the six Sustainable Development Goals (SDG) now under discussion as post Millennium Development Goals (MDGs) (Griggs *et al*, 2013). This is a significant movement, because before such initiatives, there was virtually no international organization that monitored or coordinated phosphorus management (Cordell, 2008). At the national/regional political level, the EU is moving ahead in policy debate. The European Commission has published a communication, "Roadmap to Resource Efficient Europe." Interests diverge, however, among EU member countries.

In Japan, concern about depletion of phosphorus also heightened when China imposed high duties, effectively

halting rock phosphate exports to Japan. As Japan is totally reliant on imported phosphate, a steep rise in phosphorus prices was a serious problem. This consideration prompted fertilizer industry players and recycling technology researchers to call for establishment of the Phosphorus Recycling Promotion Council of Japan, which was founded on December 18, 2008.

1.2 Why focus on recycling from domestic sewage in Japan?

A study of phosphorus flows in Japan by Matsubae *et al*. (2011) suggested a large amount of phosphorus was unused or disposed of in Japan. According to the study, recycling all of the roughly 40,000 metric tons of phosphorus that sewage contains would represent around three quarters of the 53,000 metric tons of phosphorus that Japan imports in the form of rock phosphate. This suggests that Japan has significant potential for implementing phosphorus recycling.

There has been some progress in technological development and commercialization of facilities in Japan for recycliong phosphorus in sewage. This movement could constitute an international precedence as there are still few cases of phosphorus recycling that have been put into practical operation (Yarime, *et al*., 2014). Therefore, it is worthwhile to consider what factors could encourage further development of phosphorus recycling in sewage systems in Japan.

1.3 Objective and structure of this paper

The objective of this paper is to examine obstacles and impediments and explore future issues and challenges to recycling phosphorus from sewage in Japan. For this purpose, we employ a stakeholder analysis of the actors involved (both active and potential) in phosphorus recycling processes. By doing so, we visualize the perception of problems and interests (Susskind and Jeffery., 2008). Based on that analysis, we present several policy measures and assess the feasibility of each measure.

The structure of this paper is as follows: Section 2 describes the current policies and practices surrounding phosphorus recycling in Japan; Section 3 identifies the relevant stakeholders in the phosphorus recycling processes and presents the outcome of our stakeholder analysis, identifying important issues and challenges in promoting phosphorus recycling from sewage; Section 4 discusses policy options and assesses their feasibility; and Section 5 summarizes this paper's argument and presents future challenges.

2. Current Policies and Practices Regarding Phosphorus Recycling from Sewage in Japan

This section examines the current situation with regard to phosphorus recycling from sewage systems in Japan.

2.1 Platform for phosphorus recycling

As mentioned in Section 1, the Phosphorus Recycling Promotion Council of Japan was established in response to rising concerns about phosphorus depletion and peaking prices. The aims of the council are as follows: to identify challenges in the realization of phosphorus recycling, to promote networks among the relevant stakeholders, to consider policy recommendations, and to contribute to creating a sustainable society and global environment. The council brings together experts, practitioners and institutions from academia, industry and relevant ministries. In particular, it considers the importance of overcoming sectionalism among the respective actors and serves as an "all Japan" platform for tackling the issue of phosphorus recycling comprehensively and strategically.

The efforts of a professor at Osaka University significantly facilitated establishment of the council. Another key driving actor was the Japan Fertilizer and Ammonia Producers Association. The Association was established in 2003 through a merger between the Japan Phosphate and Compound Fertilizers Manufacturers' Association and the Japan Urea and Ammonium Sulphate Industry Association, both of which began operating before World War II. The concern of the association was a shrinking trend in the trade and consumption of fertilizers (Narita, 2010) due to the gradual decline of agriculture in Japan. An important challenge the industry currently faces is to secure diverse and stable supplies amid surging raw materials prices.

2.2 Leading practices at the municipal government level

There are several initiatives led by municipal governments, including the cities of Fukuoka, Gifu and Tottori. The Road and Wastewater Bureau of the City of Fukuoka employed magnesium ammonium phosphate (MAP) crystallization to pioneer phosphorus recovery from sewage in Japan. Their goal was to prevent eutrophication of Hakata Bay. The city started to build an advanced MAP-based treatment plant in fiscal year (FY) 1993 and completed its construction in FY1999. The municipality has been selling MAP to companies that market fertilizer materials since FY1997.

In Gifu, the Waterworks and Sewage Department began to conduct research on phosphorus recovery technologies from sewage sludge ash in FY2003. It started to distribute and sell recycled phosphorus in FY2010. The main purpose of the facility is to contribute to creating a recycling-oriented society.

Tottori deployed the same recycling process as the Gifu plant, as the second such initiative in Japan. In April 2013, the Akisato Sewage Treatment Plant began full-fledged operations of a facility to recover phosphorus from incinerated sludge ash (Sewage Technology Development Project Committee, 2007).

2.3 Distributors, recycling technology and users' policies on recycled phosphorus

In order to promote phosphorus recycling, involvement of distributors for recycled phosphorus is indispensable. For that purpose, serious engagement of phosphorus manufacturers as well as fertilizer companies is critically important. Company A, for instance, manufactures and sells phosphoric acid and ammonium phosphate wholesale to fertilizer producers and other businesses. Responding to the phosphate price hike, in around 2012, Company A started using incinerated sludge ash from a wastewater treatment plant.

It is important to utilize various kinds of technological development in phosphorus recycling. There are several types of technological development that enable phosphorus recovery. There is a potential for such technology development enterprises to contribute to phosphorus recycling. Company B, for example, jointly developed a new physico-chemical phosphorus removal technique using a high-speed absorbent with the Japan Sewage Works Agency from FY2006 to 2008. In March 2012 this technology was deployed for the first time at the Kasumigaura Wastewater Treatment Plant in Ibaraki Prefecture (Japan Sewage Works Agency, 2011; Japan Sewage Works Agency, 2012). Based on the results of this demonstration, in June 2013 the Ministry of Land, Infrastructure, Transport and Tourism authorized this technique as appropriate for tertiary wastewater treatment facilities. Using this technology, the Kasumigaura facility can remove phosphorus at extremely low concentrations as small as of 0.05mg per liter and recover around 100 metric tons annually of phosphorus as hydroxyapatite, which is of sufficiently high quality to be used as a raw material for manufacturing fertilizer. The cement industry is one of the main absorbers of sewage sludge. They use sewage sludge as a raw material for manufacturing cement. In recent years, the amount of wastes among raw materials for cement has been increasing. According to statistics from the Japan Cement Association, about half of the raw materials for cement are wastes and about 10% of the waste is sewage sludge (Japan Cement Association, 2011). Sewage sludge with a high concentration of phosphorus is not suitable for cement. The cement industry hence has a potential interest in removing phosphorus from sewage when using it as a raw material for cement. For instance, Company C, the largest cement producer in Japan, with a long history, has developed high-performance phosphorus absorbent technology jointly with its affiliated chemical company. The company started to develop this technology in 2009. Test operations were conducted (jointly with the local government of Hokkaido in Hakodate) at a wastewater treatment plant, a blackwater treatment plant in Aichi and a livestock wastewater treatment plant in Chiba Prefecture. They found the extracted phosphorus could be used as fertilizer categorized as "byproduct phosphate fertilizer."

Fertilizer is one of the main applications of recycled phosphorus. For that reason, agricultural cooperatives' policies on recycled phosphorus are important. JA Zen-Noh (National Federation of Agricultural Cooperatives) collectively purchases materials needed for agricultural products and provides markets for its member farmers. JA Zen-Noh's Fertilizers and Pesticides Department imports materials which it sells to fertilizer producers and then supplies their fertilizers to JA Zen-Noh cooperatives and farms. JA Zen-Noh is engaged in diverse initiatives to promote recycled phosphorus fertilizers, including those made from poultry manure, wastewater sludge ashes and farm manure. Already available for commercialization is the Eco Kasei Series of recycled fertilizers, which incorporate poultry manure ash and are generally cheaper than conventional offerings.

3. Stakeholder Analysis

3.1 Stakeholders

We considered six stakeholders involved in recycling phosphorus from sewage: the fertilizer industry, municipalities that are recycling phosphorus (Fukuoka, Gifu and Tottori), private recyclers (Company A), technology developers for phosphorus recovery (Company B), cement companies (Company C) and agricultural entities (JA Zen-Noh, JA Branch D, farmers E and F). To consider the users' (*i.e.*, farmers') varied interests, we interviewed a representative of JA Branch D for direct contact with farmers. To solicit opinions on recycled fertilizers from farmers who used phosphate fertilizers, we drew on the results of a questionnaire survey (by the Japan Sewage Works Association, 2009). In addition, we conducted individual interviews with farmers E and F. To reflect diverse views, we selected Farmer E as a rice farmer and Farmer F as an upland farmer.

The analysis in the following sections is based on Sato *et al*. (2014), with substantial revisions, including findings obtained from interviews with the cement producer.

3.2 Analysis of stakeholders' issue perception and interests

Based on the above-mentioned interviews, we identified seven elements that stakeholders considered vital for promoting phosphorus recycling: environment, cost, image, transaction stability, distribution, quantity and quality. Table 1 compares issue perceptions and interests of stakeholders.

(1) Fertilizer Industry (Japan Fertilizer and Ammonia Producers Association)

The main reason for the fertilizer industry to promote recycling is to diversify their supply sources. Rising raw materials prices, expanding demand in emerging nations and declining demand in Japan have compelled the Japan Fertilizer and Ammonia Producers Association to explore alternatives to the current dependence on imports. That organization has positioned recycled phosphorus as a secondary source to ensure supply diversity.

Table 1 Comparative analysis of stakeholder issue awareness. S= Strong, M= Moderate, Blank= No or Weak

	Environment	Cost	Image	Transaction	Distribution	Quantity	Quality
Fertilizer Ind.	S	S	S		S	S	S
Municipalit.	S	M		S	M		
Recyclers		S			S	S	S
Technology developers	M	S			S		S
Cement Co.	S	S	S	S	S	S	S
JA Zen-Noh		S			S	S	S
JA branch	M	S					
Farmers	M	S					S

Their concerns and interests are ensuring the quality and quantity of recycled phosphorus and establishing a recycling-based structure.

To promote recycled phosphorus, it is important to meet the quality standards specified in the *Fertilizer Control Act*. It is also vital to secure sufficient distribution volumes. The association recognizes that one major challenge facing sewage-derived recycled phosphorus will be to overcome the stigma of the sludge's origin.

The association considers it necessary to put in place a cornerstone for sharing the recognition of the issue among the relevant ministries, agencies and stakeholders. This was the biggest factor in the creation of the Phosphorus Recycling Promotion Council. The association also deems it necessary to reinforce collaboration with such bodies as the Japan Sewage Works Association to establish a system based on recovery and recycling, rather than just removal, of phosphorus from sewage for which recycling is commercially viable.

(2) Recyclers: municipalities

a. Fukuoka City

The most important reason Fukuoka City engages in phosphorus recycling is not for the purpose of phosphorus recycling *per se*, but from the need to combat the eutrophication of Hakata Bay. From the outset, the city was interested in setting up a facility to prevent eutrophication. It needed to reach the target prescribed under the Hakata Bay Basic Plan for Advanced Treatment in Specified Water Areas of June 1998. The city has achieved its target (0.5mg per liter), with an average phosphorus content of 0.17mg per liter. (On the other hand, there is another concern. Seaweed farmers see Hakata Bay's declining phosphorus density as undesirable for fish, so the city needs to review its stance on phosphorus recovery).

A major concern to Fukuoka City is the cost of manufacturing MAP. Currently, MAP manufacturing is considered a loss maker in the wastewater treatment service. It only makes what it can get from sludge processed in the wastewater treatment. It has provided minimal maintenance for the MAP facility because of budget constraints. A particularly costly process is pipe cleaning, which requires chemicals that account for up to 60% of the entire cost. The city has no plans to expand MAP recovery because that would further increase losses.

Fukuoka City has more of an interest in cultivating stable business partners than in achieving short-term profits. As it is in their interest to have long-term sustainable business partnerships with fertilizer companies, even when there were inquiries from several MAP buyers when phosphate prices climbed, they refused to sell them the fertilizer. On top of that, the city seeks to promote trade within Kyushu to maintain business stability. As a provider of public services, the municipality considers it improper to implement business continuity solely on the basis of profitability. The city will make efforts to keep producing MAP, continuing to operate wastewater treatment plants and maintain and safeguard the environment even if sales stagnate.

b. Gifu City

The reason Gifu City is implementing recycling is to realize a recycling-oriented society. Before deploying the new technology, Gifu City recycled incinerated sludge ash by using it in brick-making. As production facilities aged, however, the city sought new recycling techniques, considering phosphorus recovery to match the municipality's vision of creating a recycling-oriented society.

Their concern, however, has been the cost. Phosphorus recovery costs are a burden, given that sales of calcium hydroxyapatite and ash byproducts generate only several millions of yen, insufficient for offsetting the costs. Losses notwithstanding, the municipality is pushing ahead with this setup under its strong commitment to achieving a recycling-oriented society. The current cost of phosphorus recovery is manageable, compared with the previous approach of making bricks or other alternatives, such as disposal of ashes as landfill. Therefore, the municipality considers some losses acceptable as a necessary cost.

Gifu City has little incentive to increase the supply. Its losses will expand if it tries to increase it at the current price level. In addition, only a limited volume of ash can be collected because under the current legal system it is hard to bring in sewage sludge categorized as waste from outside the municipality.

Another concern is shortfalls in sales channels. The municipality sells its Gifu-no-Daichi (Gifu's Land) fertilizer to farmers through local JA branches. The municipality also ships phosphorus to fertilizer companies. Demand from fertilizer companies is set to exceed the municipality's supply capacity. Having once found it

hard to cultivate new sales channels when demand slowed down, the municipality worries about demand disappearing again. This discourages it from seeking to improve profitability by raising prices. Furthermore, public servants consider themselves poor business people, and are thus reluctant to get directly involved in commercial activities

c. Tottori City

As with Gifu City, the main motivation for launching a phosphorus recycling business was a need to resolve problems in the sludge disposal process, rather than simply to lower phosphorus concentrations in wastewater. The phosphorus recovery process constitutes a win-win situation as it will reduce the disposal costs of ash with components typical of hot-spring areas and will contribute to the effective use of the phosphorus in the ash. It also reduces disposal charges for ash that the municipality was previously unable to reuse in cement because of the high phosphorus content. While Gifu City sought to sell the phosphorus by itself, Tottori City decided from the outset to commission JA Zen-Noh to sell the phosphate on the condition that the sales be restricted to Tottori to promote local consumption.

As it only started operations in April 2013, the municipality is not ready yet to identify specific problems. Still, as the recovery of phosphorus fluctuates with seasons and temperatures, the municipality thinks that one issue will be to maintain constant quality.

(3) Recycling practitioners: Company A

Company A uses imported rock phosphate and recycled phosphorus made domestically from ash to produce phosphoric acid. Made-in-Japan phosphoric acid is not necessarily cheaper than that produced overseas. Still, Company A has been able to build its business with customers who take into account the need for geographical risk management and phosphorus recycling.

Cesium contamination of ash has been a serious problem since the nuclear power plant accident in Fukushima in March 2011. Company A has had to procure high-quality ash from areas far away from the Kanto region, where the company is located. The company tests ash for radioactivity in quality management, and this process is very costly.

One challenge will be filling the need for quality ash. To promote phosphorus recycling from ash, it will be necessary either to find wastewater treatment plants that generate high-quality ash, as the density of phosphorus varies from plant to plant, or to encourage municipalities to adopt new systems so that they can produce high-quality ash. Research and development on removing impurities from ash is also important, and Company A is also involved in such activities.

(4) Technology developer: Company B

Company B's motivation for engaging in phosphorus recovery is to make effective use of their own technologies. In the early 2000s, Company B developed a high-speed absorbent technology, for which it has been seeking applications since then. The company initially considered commercializing phosphorus-removing technology for improving effluent quality. With the 2008 phosphate price hike, however, Company B decided to focus on phosphorus recovery and launched joint research with the Japan Sewage Works Agency to engage in subsequent pilot operations.

Company B's technology made it possible to obtain high-quality phosphorus with high removal and recovery rates, and high durability and recyclability through repeated absorption and desorption. The question is whether municipalities actually need such advanced technology. It will be necessary to work with municipalities who need to deal with effluents being discharged into enclosed water systems, as in the case of Lake Kasumigaura.

(5) Cement producer: Company C

The purpose of Company C's work on phosphorus recycling was to promote its business by making use of a technology which the corporate group had already developed. By using a high-performance phosphorus absorbent, this technology can reduce the concentration of phosphorus in sewage and industrial wastewater. This enables the company to increase the amount of sewage waste it receives and thus produce more raw materials for making cement. It could also contribute to moving towards a sustainable recycling society. To promote this, Company C points out that wastewater treatment plants should change their perception not only to comply with effluent standards but also to consider recovering and making use of discarded materials. The company believes that it is important to create incentives to enhance the acceptability to farmers of making efficient use of recycled phosphorus from sewage. It also seeks to expand its market by deploying this technology for diverse applications such as treating livestock wastewater.

(6) Agricultural Entities

a. JA Zen-Noh (Fertilizers and Pesticides Department)

JA Zen-Noh's major interests include providing a stable supply of fertilizer, containing fertilizer prices and developing recycled fertilizers from diverse resources. For these purposes, JA Zen-Noh considers it important to deploy recycled phosphorus fertilizer. Zen-Noh is looking at more than just sewage recycling. It is focusing particularly on making fertilizer from poultry manure ash. The revision of *Fertilizer Control Act* specifications has made it possible to use farm manure as regular fertilizer. Although mixing compost and chemical fertilizers was prohibited previously, the new specifications permit such blending, as long as the components are strictly controlled. Following this regulatory change, Zen-Noh started developing such fertilizers with data generated from tests. This form of recycling entails shipping compost to a fertilizer manufacturer for mixing. That requires odor management, but few fertilizer manufacturers are

able to control odors. The types of compost usable in fertilizers are currently limited to swine and poultry because it is difficult to process cow manure into fertilizer as it often contains straw and other impurities.

Sewage sludge can be manufactured, distributed and sold as sludge fertilizer (regular fertilizer). JA Zen-Noh has little control over distribution, which is mainly carried out by local JA branches. A major concern with the use of the recovered P products is that phosphorus from incinerated sludge ash may be in a form that is unavailable for crops, as the phosphorus is combined with iron or aluminum. Hence processing it into fertilizer is a challenge. Nevertheless, Zen-Noh believes that it is possible to use sludge ash as a fertilizer or raw material for fertilizer by extracting or concentrating phosphorus or changing the configuration to make it crop-friendly. Heavy metals and other hazardous elements have to be removed in the process. As mentioned earlier, it is also important to ensure that farmers benefit from using fertilizer based on domestic raw materials. Zen-Noh considers it necessary to manufacture and supply fertilizer that is cheaper than the products of existing raw materials.

b. JA Branch D

JA Branch D recognizes that the interests of farmers vary according to their area. Interest in appropriate fertilizer application depends on whether a farm's main crop is produced in greenhouses or rice paddies. Geography is also an important factor, as some areas are more susceptible than others to water pollution caused by fertilizer use. Hence local conditions influence the interests of farmers.

JA Zen-Noh's Fertilizers and Pesticides Department has not yet shared details about phosphorus recovery initiatives with its branches, which cannot act without specific instructions from JA Zen-Noh.

The local JA branch considers farmers to have little awareness of the possibility of phosphorus depletion, an issue still remote to them. Unless recycled phosphorus fertilizer becomes cheaper than other fertilizers, they will not be very interested in the recycled fertilizer. Farmers focus on the costs, in particular, of individual materials, such as fertilizer and improved materials, so if recycled fertilizer is expensive, they will not see the benefit of using it.

c. Individual farmers (Farmer E cultivating rice in Ibaraki Prefecture and Farmer F growing celery and other vegetables in Shizuoka Prefecture)

The farmers consider recycled fertilizer relatively expensive and believe that affordability is the prime factor in its diffusion. Also, they seek to minimize the labor involved in applying fertilizer to farmland and hence prefer a product offering easy application even if it is slightly more expensive.

An interesting point learned from the interviews was that these farmers think that phosphorus recycled from sewage does not differ from compost. This implies they do not necessarily view this resource negatively as other stakeholders would. They would not hesitate to use recycled phosphorus if information about the components and safety were disclosed so that they could make their own judgments based on the information. On the other hand, they want to know if the fertilizer contains radioactive substances or heavy metals because of the potential impact on crop and product safety.

A questionnaire survey on sewage-derived fertilizer conducted by the Japan Sewage Works Association (2009) basically underscores this image of recycled phosphorus among individual farmers.

4. Assessment of Policy Measures for Phosphorus Recycling

4.1 Important factors in promoting phosphorus recycling

The key stakeholders focusing on environmental protection are municipality sewage bureaus. Their interests depend on the particular environmental conditions that these municipalities face. For Fukuoka City, the prime environmental challenge is to overcome eutrophication in Hakata Bay, an enclosed sea area. For Gifu City and Tottori City, phosphorus discharges are lower than mandated. Other dimensions, such as creating a recycling-oriented society and improving environmental conditions, are also important in implementing recycling.

Since all stakeholders emphasize costs, the key to successful phosphorus recycling would be whether it is possible to construct a system that benefits all stakeholders by offsetting their costs.

Fertilizer manufacturers view image as important. They think recycled phosphorus made from sewage sludge would be stigmatized and that farmers would not accept recycled phosphorus unless the stigma were eliminated. It is interesting to note here that farmers (although the sample size was admittedly small) do not necessarily worry about the image of sludge. They will use it if the safety and quality of the product is guaranteed, and its price is not excessively high.

Municipalities are concerned about transaction stability. As they are responsible for waste disposal, they are more interested in ensuring transaction stability for wastes than worrying about the costs involved.

Distribution is one of the most serious concerns for stakeholders involved in phosphorus recycling. If distribution is not ensured, the phosphorus will have no destination after being recovered. Municipalities have little expertise in conducting commercial business, as they are public entities. From the user perspective, however, it is necessary to enhance the convenience and value of ther recycled phosphorus as well as to offer cost advantages in order to replace existing fertilizers with recycled phosphorus. By providing additional advantages, it would be possible to enhance the competitiveness of recycled phosphorus in fertilizer distribution networks.

The quantity of products is extremely important. For recycled phosphorus to reach store shelves across Japan,

a large distribution volume is essential. It is currently difficult to conduct transactions with large distributors because the quantity of recycled phosphorus is relatively limited due to high recovery costs. It is difficult to ensure production volume when a plant cannot operate efficiently because raw materials are in short supply or the plant is too small in the first place. (With regard to recycling from wastewater in Fukuoka City, for example, it was difficult to collect sludge because each sewage facility was required to treat sludge by itself). Nevertheless, it would be possible to recover phosphorus more efficiently from ash than from wastewater, as it is possible to stockpile ash in one place. But even in that case, the *Sewage Act* has restricted Gifu City from collecting ash from nearby local towns, only allowing it to gather this material from sewage plants within its jurisdiction. As a result, the plant could not operate at full capacity with such small volumes of ash, and was prevented from running profitably. The *Sewage Act* is thus a serious impediment that Gifu City faces to producing sufficient volumes. At the same time, the plant needs to be expanded to increase its production volume. That, however, would require a significant initial investment, which would make it difficult for the municipality to recoup it later. Makers of fertilizer materials secure stable supplies of raw materials by accepting ash treated as disposable waste almost for free from distant wastewater treatment plants.

Finally, the quality of the products is a major concern for most stakeholders in stabilizing phosphorus recycling.

4.2 Identification of policy measures

Based on the areas of interest discussed above, we set out to identify measures that would contribute to improvements in terms of cost, transaction stability, sales channels, image, quantity, and quality and categorized them by assessing the feasibility of each measure from three perspectives (Table 2).

Perspective 1: Measures leading to improvements from the point of view of multiple stakeholders' interests and thus likely to attract enough support. (Majority Support)

Perspective 2: Specific measures satisfying multiple interests by resolving different issues at the same time (*dosho-imu*, a Japanese phrase meaning "sharing the same bed, dreaming different dreams." (Shiroyama *et al* (2012))

Perspective 3: Sets of measures that could enable bargaining between multiple stakeholders. (Bargaining)

This is a simplified version of the options generation and feasibility analysis features of the problem structuring technique developed by Kato and others (2013). With this technique, we identified policy measures/options from an interests/values and environmental conditions matrix. This study, however, focused on measures that stakeholders cited and did not systematically consider environmental conditions. We therefore identified measures based solely on interest items.

We listed the following concrete measures that would contribute to improvements in each interest/concern (Table 2).

a. Cost-cutting technological developments

For municipalities and businesses engaged in recycling, cutting costs is a top priority. Technological developments that contribute to cost reductions are crucial.

b. Improving the image of recycled phosphorus fertilizers

Fertilizer manufacturers believe that farmers' negative image of recycled fertilizer from sludge would represent a major challenge in promoting such fertilizer.

c. Enhancing phosphorus removal through collaboration between stakeholders

This would promote environmental protection and expanded use of sewage sludge for producing cement through collaboration between municipalities and cement producers. Several municipalities that recycle phosphorus look beyond just resource recovery, intending to safeguard enclosed seas and achieve recycling-oriented societies. On the other hand, cement producers are interested in increasing the use of sewage sludge with low levels of phosphorus, which would provide them increased amounts of raw material for producing cement. Therefore, enhanced removal of phosphorus from sewage sludge could be pursued through collaboration between municipalities with stringent environmental targets and cement producers with an interest in increasing the volume of sewage without phosphorus.

d. Developing distribution channels through collaboration between stakeholders

If several municipalities together concluded an agreement with a fertilizer manufacturer or cement producer for jointly developing sales channels, they could stabilize transactions.

e. Building localized production and consumption systems

Table 2 Comparison of feasibility assessment of measures. H= High feasibility, M＝Moderate feasibility

Measure	Assessment
a. Perspective 1 (Majority Support)	
1. Cost-cutting technological developments	H
2. Improving the image of phosphorus fertilizers recycled from sewage	M
b. Perspective 2 (*dosho-imu*)	
1. Enhancing removal of phosphorus from sewage through collaboration between stakeholders	H
2. Developing distribution channels through collaboration between stakeholders	H
3. Building localized production and consumption systems	M
c. Perspective 3 (Bargaining)	
1. Combining municipalities' efforts to share costs and benefits	H

Promoting such systems could attract more municipalities to become involved in recycling.

f. Combining municipalities' efforts to share costs and benefits

By working together, municipalties could improve the quality of recovered P products and secure better payments from fertilizer manufacturers. Efforts by municipalities to enhance waste quality from sewage operations, could help lower recycling costs. Incentives could be created by combining high-quality wastes and better payments from fertilizer producers to municipalities for those resources.

4.3 Assessment of policy measures

In this study, through stakeholder interviews and assessment of feasibilities, we identified and analyzed potential measures that could be adopted. Here, we define feasibility as the potential for stakeholders to form a consensus. We considered three possibilities: majority support, possible support by stakeholders with different intentions but shared means (*dosho-imu*), and bargaining by combining some interests. The following table presents the results of feasibility assessments and shows which of the three patterns corresponds to each measure.

a. Perspective 1 (Majority Support)

(i) Cost-cutting technological development

This measure is viewed very positively, with support from many stakeholders. They include municipalities, fertilizer manufacturers, cement producers and technology developers.

(ii) Improving the image of recycled phosphorus fertilizers

Fertilizer manufacturers support this measure. It is not, however, regarded very important among farmers, whose interest is less in the image of the product and more in ensuring its safety.

b. Perspective 2 (*dosho-imu*)

(i) Enhancing phosphorus removal through collaboration between stakeholders

This measure gained possible support from more than two stakeholders with different interests but sharing the same means. These included municipalities focusing on achieving environmental objectives and cement producers who were interested in increasing the use of sewage sludge with low levels of phosphorus..

(ii) Developing distribution channels through collaboration between stakeholders

This had potential support from two stakeholders with different interests but sharing the same means: a municipality wishing to ensure ongoing transactions and a fertilizer manufacturer/cement producer wanting to procure stable volumes.

(iii) Building localized production and consumption systems

It is possible to have different intents but share the same means, for example, municipalities interested in creating a recycling-oriented society and fertilizer manufacturers wishing to ensure sufficient and stable procurement. Although fertilizer manufacturers do not necessarily care very much about procuring locally, their locations are regionally dispersed, so they can collaborate with municipalities to establish a system for local production and consumption of fertilizers made from sewage. Farmers, however, do not necessarily support this approach.

c. Perspective 3 (Bargaining)

(i) Combining municipalities' efforts to share costs and benefits

By working together municipalities could improve the quality of recovered P products and secure better payments from fertilizer manufacturers for higher quality phosphorus.

Fertilizer manufacturers/cement producers seek quality products while municipalities seek to increase revenues by improving the quality of recovered products (or by reducing costs). It would therefore be possible to bargain by combining the interests of both parties.

Figure 1 shows the relationships among the stakeholders involved in phosphorus recycling from sewage, based on Ohtake (2010), with potential measures feasible for some of the stakeholders also indicated. The squares represent phases of the phorphorus recycling process, whereas the rounded boxes represent the stakeholders involved in the recycling process.

5. Conclusions and Challenges

Rock phosphate reserves are considered close to depletion worldwide, and will dwindle in the long run. As Japan imports all of its phosphate, its agricultural and industrial sectors are concerned about the massive prospective impact of higher phosphate prices. Japan thus needs to create a sustainable phosphorus production and consumption cycle that does not rely solely on imports. Phosphorus recycling is attracting considerable attention as a potential solution. Although some municipalities promote phosphorus recycling from sewage, this is still far from common nationwide.

In this paper, we analyzed the stakeholders involved in phosphorus recycling and identified vital factors in the promotion of phosphorus recycling, namely, environment, cost, image, transaction stability, distribution, quantity, and quality. Based on that, we developed policy measures for consideration from three perspectives (majority support, *dosho-imu*, and bargaining) and assessed the feasibility of these measures. Among the measures assessed to have higher feasibility were cost-cutting technological developments; collaboration between municipalities (interested in the environment) and cement producers (interested in expanded use of sewage sludge with less phosphorous content); establishment of distribution channels between municipalities, fertilizer makers and cement producers; and sharing of the costs and benefits among municipalities, fertilizer makers and cement producers.

New knowledge gained from this research, in comparison with recycling in other fields, is as follows. The stakeholders involved in phosphorus recycling are far

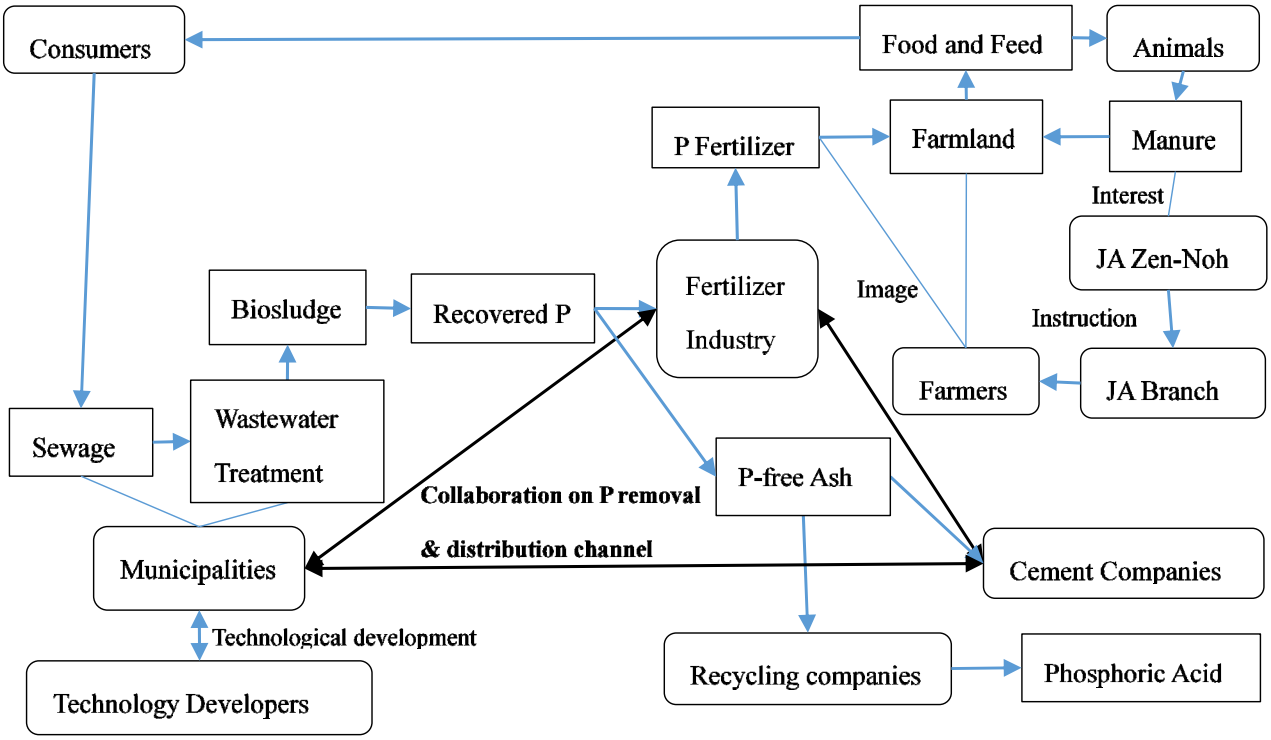

Fig. 1 Relationships among the Stakeholders Involved in Phosphorus Recycling from Sewage.

more diverse than those in industrial materials recycling. It is therefore vital first to conduct stakeholder analysis as has been done in this paper to identify the interests and concerns of the related actors and then to consider policy strategies for better collaboration from a systemic perspective. Our policy measure assessment suggests that even those who do not share "the same" objective may have a potential incentive to agree with other actors on the same measure to achieve their multiple diverse objectives (as was presented in the *dosho-imu*). For this to happen, however, there must be a platform that would be effective in facilitating collaboration. We believe that to promote the measures presented in this paper, it will be crucial for the entire nation to create a vehicle to promote collaboration between municipalities and the fertilizer industry/cement industry and to ensure the inclusion and participation of the relevant stakeholders.

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